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ANOPP / VMS HSCT GROUND CONTOUR SYSTEM

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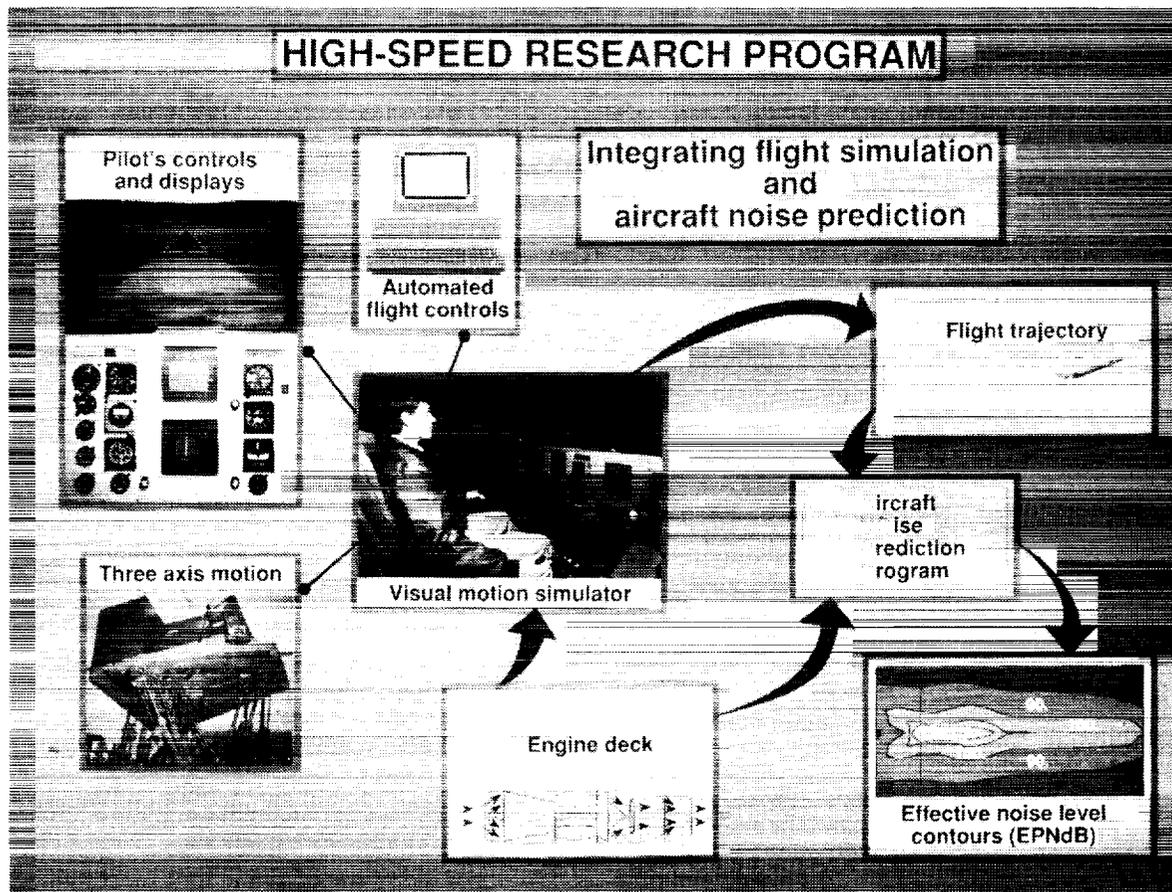
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HIGH-SPEED RESEARCH PROGRAM

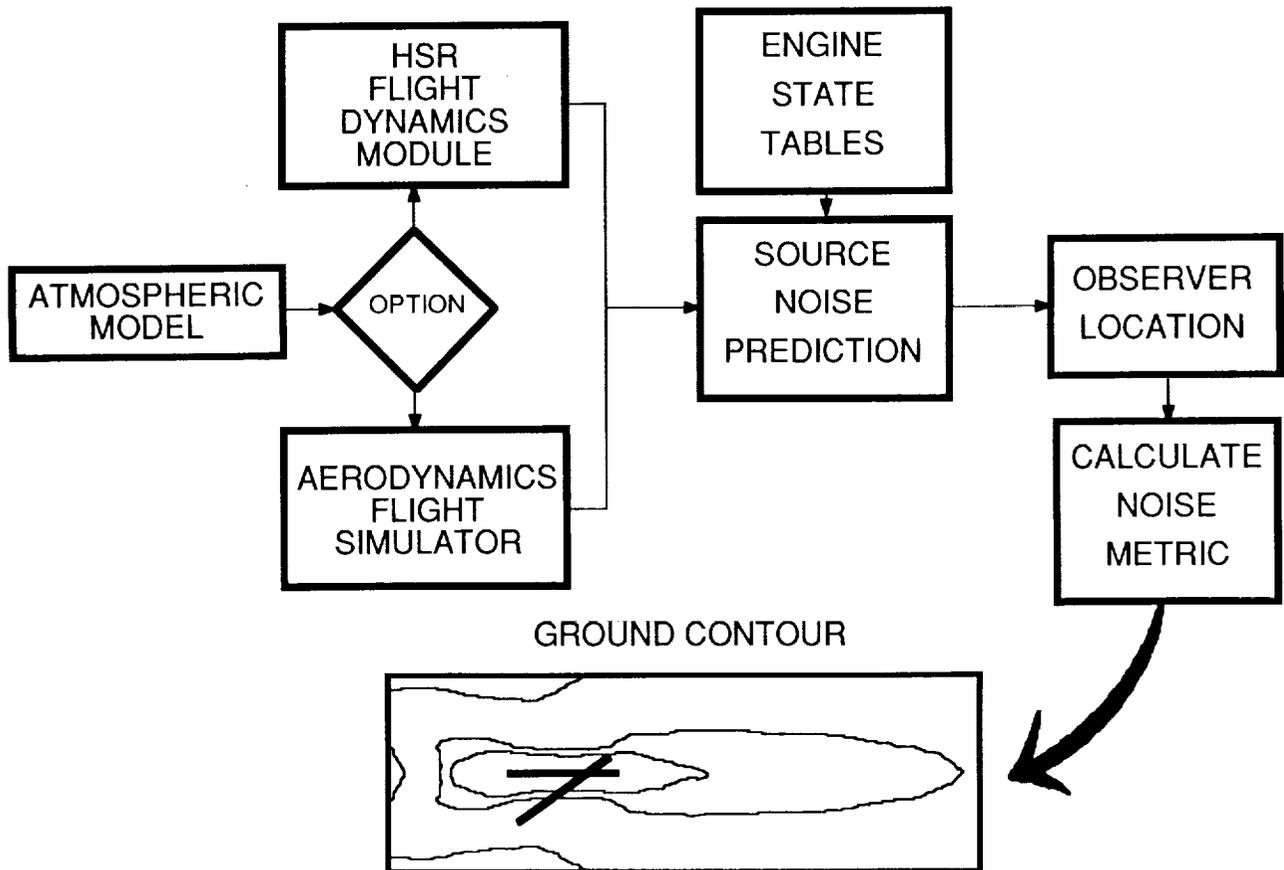
This viewgraph shows the integration of the Visual Motion Simulator with ANOPP. ANOPP is an acronym for the Aircraft NOise Prediction Program. It is a computer code consisting of dedicated noise prediction modules for jet, propeller and rotor powered aircraft along with flight support and noise propagation modules, all executed under the control of an executive system. The VMS is a ground based motion simulator with six degrees of freedom. The transport-type cockpit is equipped with conventional flight and engine-thrust controls and with flight instrument displays. Control forces on the wheel, column, and rudder pedals are provided by a hydraulic system coupled with an analog computer. The simulator provides variable-feel characteristics of stiffness, damping, coulomb friction, breakout forces, and inertia. The Visual Motion Simulator provides a wide range of realistic flight trajectories necessary for computing accurate ground contours. The NASA VMS will be discussed in detail later in this presentation. An equally important part of the system for both ANOPP and VMS is the engine performance. This will also be discussed in the presentation.



HSR NOISE PREDICTION SYSTEM

This viewgraph shows a diagram of the functional path that is used by ANOPP to execute a prediction for airport community noise. It shows the types of prediction modules that are required to perform the prediction and the order in which they are executed. To produce the contours, the normal ANOPP output pass through a formatting program and then to a contour plotting program. A contour plotting program to accompany ANOPP is under development.

HSR NOISE PREDICTION SYSTEM



UPDATES TO HSR SYSTEM

The HSR Noise Prediction System started as the Conventional Take-Off and Landing (CTOL) System completed by NASA in 1982. This viewgraph shows updates that have been made for the HSR System.

UPDATES TO HSR SYSTEM

- Incorporated two new Flight Dynamics Modules
 - JTO - Jet Takeoff Module
 - JLD - Jet Landing Module
- Added atmospheric absorption coefficients developed by Dr. Zuckerwar
- Updated Jim Stone jet noise prediction method to include modification made after the CTOL system was completed in 1982
- Developed a formatting module to produce an output file for plotting EPNL, Max. A-weighted, and/or Max. PNLT
- Coupled the HSR Noise Prediction System with the Visual Motion Simulator
- Coupled Engine State Tables produced by the Navy NASA Engine Program (NNEP) with ANOPP

CURRENT WORK & FUTURE PLANS

This viewgraph is self explanatory.

CURRENT WORK

- Developing a contour plot program to accompany the HSR Noise Prediction System
- Investigating the noise problem associated with climb-to-cruise
- Developing TEMPLATES to better explain the use of the HSR Noise Prediction System

FUTURE PLANS

- Incorporate into the HSR Noise Prediction System two new jet noise modules based on the MGB and MS codes developed by GE
- Incorporate into the HSR Noise Prediction System a broadband shock noise module based on the theory of C. Tam

ENGINE STATE TABLES

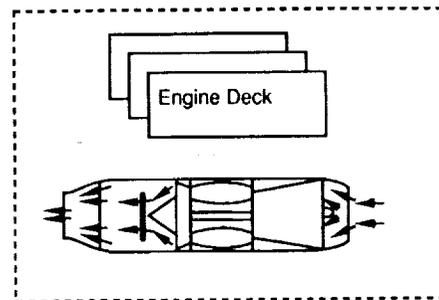
The Engine State Tables provide the acoustic input parameters to the noise modules as a function of the aircraft Mach number and the engine power setting. An engine state table is required at the inlet and the exit of the fan, combustor and the turbine. A single engine state table is required for a single flow nozzle such as a turbojet jet. An additional table is required for dual flow nozzles. Each engine state table has the same format so that the same computer code can be used to read the tables. As shown, the first entry into the table is the area (for example the jet exit area), the second is the fuel-to-air ratio, the third is the mass flow rate, the fourth is the total temperature, the fifth is the total pressure and the last is the rotational speed. A takeoff noise prediction requires hundreds of input parameters since the aircraft Mach number continually changes. The takeoff profile can be further complicated by power changes due to cutback. The Engine State Tables are provided to ANOPP by the Vehicle Integration Branch in the Advanced Vehicle Division. Currently, the computer code used to generate the Engine State Tables is the Navy NASA Engine Program or NNEP.

ENGINE STATE TABLES

Provide acoustic input parameters to noise modules for a specified range of power settings and Mach numbers

[Area, Fuel-to-Air Ratio, Mass Flow Rate, Total Pressure, Total Temperature, Rotational Speed]

| | |
|---------|-----------|
| FAN | INLET |
| | EXIT |
| CORE | INLET |
| | EXIT |
| TURBINE | INLET |
| | EXIT |
| JET | PRIMARY |
| | SECONDARY |



An engine deck consisting of 6 power settings, 5 Mach number, 4 noise sources, 6 parameters for inlet and exit conditions = 1440 entries

Engine State Table output directly from Navy NASA Engine Program (NNEP)

USE OF ENGINE STATE TABLES IN ANOPP

The Engine State Tables are provided as an ASCII file in a format that can be incorporated directly into an ANOPP program. Shown on the left side of this viewgraph is a representation of an ANOPP program starting with the ANOPP \$ statement and ending with the ENDCS \$ statement. The engine state tables are input prior the four CALL PROCLIB(noise source) statements. ANOPP automatically computes the input parameters required at each point along the takeoff trajectory from the Engine State Tables. This is shown graphically on the left side of the viewgraph.

USE OF ENGINE STATE TABLES IN ANOPP

ANOPP \$

•
•
•

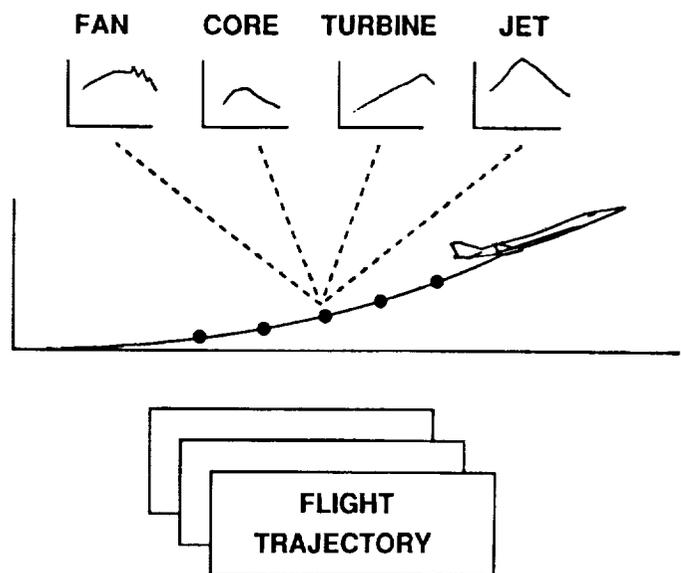
*INSERT ENGINE STATE TABLES
VIA EDITOR*

CALL PROCLIB(THDNFAN) \$
CALL PROCLIB(TGECOR) \$
CALL PROCLIB(TGETUR) \$
CALL PROCLIB(TSTNJET) \$

•
•
•

ENDCS \$

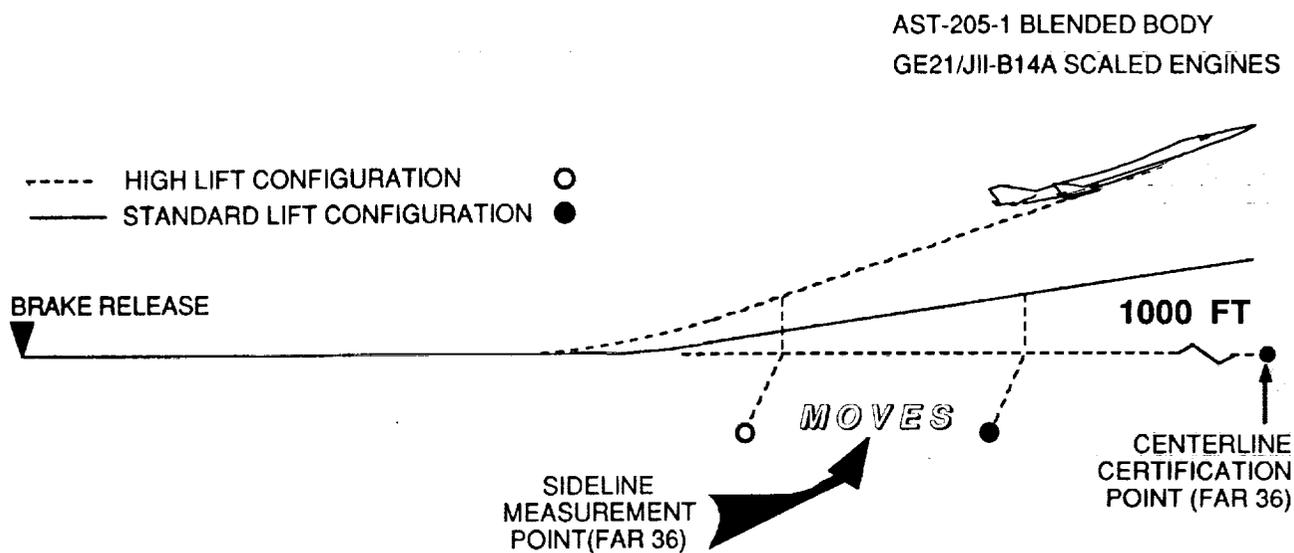
TYPICAL TAKEOFF NOISE PREDICTION
1/2 SECOND INTERVALS
150 SECONDS



HSR TAKE-OFF FLIGHT PROFILES

This viewgraph shows the details of the aircraft flight dynamics and the two certification positions involved in the execution of the high lift noise prediction take-off problem. It depicts two cases for take off, one a power setting of 100% and a normal lift configuration, and another which depicts the use of high lift to rotate and lift off earlier. The centerline FAR 36 measurement is far enough down range so that most modern turbine engines and aircraft do not have a problem meeting the requirements. The problem with more modern turbofan powered aircraft as is true for the HSCT is meeting the requirement of the FAR 36 sideline point. This point remains 1476 feet from the centerline of the flight path but is adjusted to the flight profile. Experience has show that the peak sideline noise level occurs when the aircraft reaches an altitude of 1000 feet. The FAA allows the passage through this altitude to be the sideline measurement point. As shown in the viewgraph, the sideline measurement point for the high lift case is closer to brake release than for the standard lift case. Any noise gain will have to be a result of the aircraft being able to climb out at a steeper angle so that the reduction in noise is proportional to $20 \log r$, where r is the distance between the measuring point and the aircraft. There will also be a similar noise benefit at the downrange centerline measuring point.

HSR TAKE-OFF FLIGHT PROFILES



FOR DISTANCE R , $SPL \propto 20 \log R$

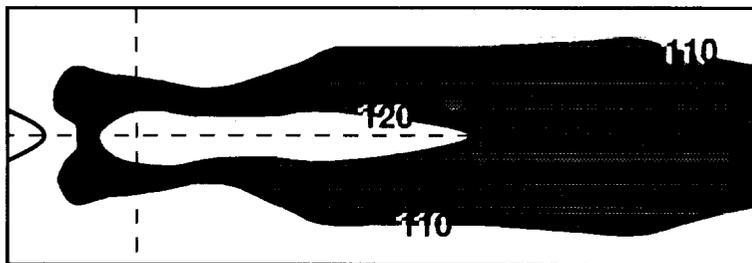
FOR JET VELOCITY V , $SPL \propto 65 \log V$

ANOPP SYSTEM NOISE PREDICTION FOR HSCT
Effective Noise Level Contours (EPNdB)

This viewgraph shows predicted results using the HSR Noise Prediction System that demonstrates an alternative way to utilize the benefits of high lift. That is to use the high lift to reduce the jet thrust. The advantage of this technique, like a power cut back presently used with current turbofan aircraft, is that the reduction in noise is proportional to $65 \log V$, where V is the jet exhaust velocity. The two color contours explicitly demonstrate the differences in contour areas between a 100% thrust, standard lift configuration for take-off and the use of a 80% thrust, 60% increase in lift where the increased lift has been utilized by providing the reduced thrust. The values to the right of the contour show the reduction in the sideline and centerline EPNL values due to changes in thrust and lift. (It should be mentioned that increases in lift of these magnitudes would require significant technological advances. For this study increases in lift were assumed to result from increasing L/D with no increase in drag. A constant rotation of 3 degrees per second and a subsequent constant climb angle of 8 degrees was used in both cases.) The results show clearly that the greatest gain for reducing the sideline noise level comes from using the high lift to reduce jet thrust.

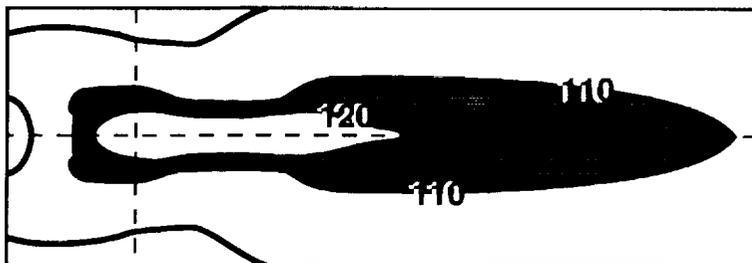
ANOPP SYSTEM NOISE PREDICTION FOR HSCT
Effective Noise Level Contours (EPNdB)

100% THRUST, STANDARD LIFT CONFIGURATION



- Sideline 116.3
- Centerline 116.2

80% THRUST, 30% LIFT INCREASE



- Sideline 112.3
- Centerline 112.2

●, ● Noise certification points

HSCT Piloted Simulation Background

The piloted simulation effort resulted from the projected inability of current HSCT concepts to meet proposed noise regulations.

Previous studies have shown reductions in airport-community noise resulting from:

- Increases in C_L
- Advanced takeoff and landing operating procedures
- Modifications to engine characteristics

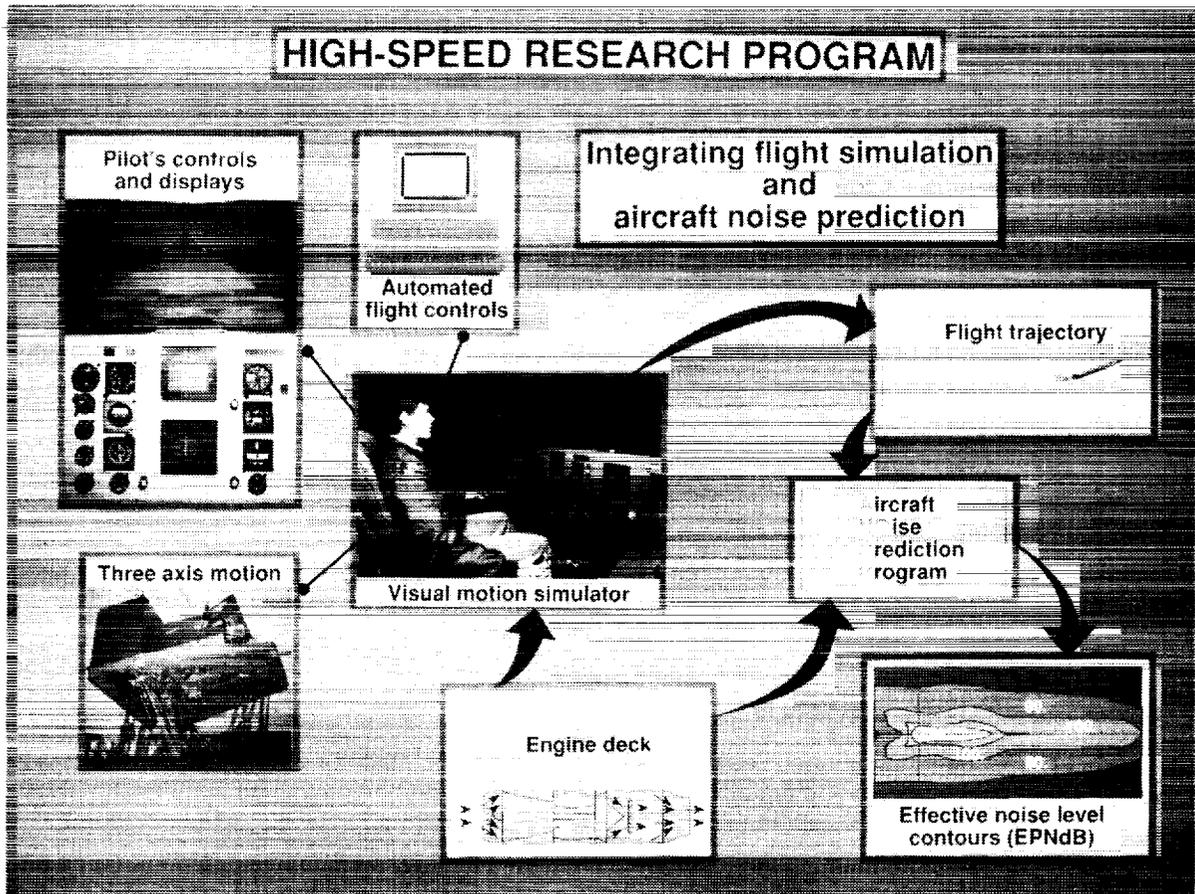
HSCT Piloted Simulation Objectives

The objectives of the piloted simulation program are as indicated.

- Document noise reduction resulting from increase in C_L and L/D and modifications to engine characteristics
- Develop and evaluate advanced takeoff and landing pilot operating procedures, which fully exploit noise reduction benefits without compromising safety

HSCT Piloted Simulation Approach

The approach to noise prediction is shown on the accompanying chart. The research uses the Langley Visual Motion Simulator (VMS) which has three axis motion capability (three axis translation and three axis rotation). The pilot has a standard display panel and controls, and a computer graphics image of the runway and airport surroundings. The simulation provides automated flight control capability and allows different levels of stability augmentation systems to be considered. The pilot can perform take-off and landing procedures and the resulting flight trajectories (coupled with the engine characteristics) are input to the Aircraft Noise Prediction Program (ANOPP) which is then used to compute noise contours. An initial objective of this research effort was to develop the VMS/ANOPP interface. To permit rapid accomplishment of this objective, the AST-105 configuration (because of the available and comprehensive data base) was selected for initial study.



Current Simulator Capabilities

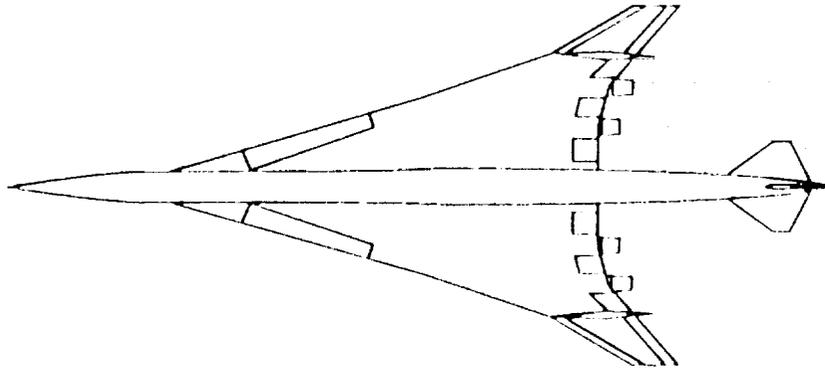
The current simulator capabilities are as shown. A six degree of freedom Visual Motion Simulation (VMS) provides the aircraft motion cues. The atmosphere model for this simulation is capable of simulating numerous meteorological conditions including varying turbulence levels, wind direction and magnitudes as well as non standard conditions. The computer generated pilot visual scene provides the pilot with both front and peripheral views on a total of four simulated cockpit "windows". Various flight conditions can be simulated using this system, for example a flight at night with thunderstorm activity. The pilot is provided flight information from a suite of computer generated CRT displays, which include an Electronic Attitude Director Indicator (EADI), Horizontal Situation Indicator (HSI) and engine data information. Currently the pilot is provided with a sidestick controller, rudder pedals, engine throttles and wing spoilers. The engines can be controlled either manually via the four power levers or automatically using the auto-throttle option, which consists of an indicated airspeed hold system.

CURRENT SIMULATOR CAPABILITIES

- 6 Degree of freedom motion simulation
- Variable atmosphere model
- Computer generated out the window visual scene
- Computer generated pilot information displays (EADI, HSI, and engine data)
- Sidestick controller, rudder pedals, engine throttles and wing spoiler controls
- Auto-throttle (indicated airspeed hold)

HSCT Simulation Baseline Configuration

Due to the existence of a comprehensive data base the AST-105 configuration was selected as a simulation model. Although this configuration was developed in the late 1970's it is representative of current HSCT conceptual designs.



Airframe AST-105-1 (1979)

$W_{T.O.}$ (lbf) = 686,000

$W_{App.}$ (lbf) = 392,250

S (ft²) = 8366

b (ft) = 126.215

c (ft) = 88.162

$\Delta L.E.$ (deg) = 74/70.3/60

Range (n. mi.) = 4500

M_{cruise} = 2.7

T/W = 0.254

L/D_{max} = 9.39

Engine (4) VSCE-516 (1979)

Bypass ratio = 1.3:1

OPR = 16:1

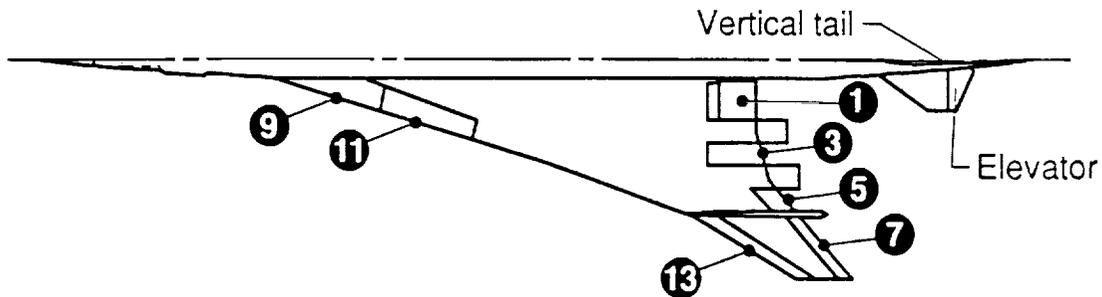
W_a (lbf/sec) = 608

V_f/V_p = 1.7:1

Control Surface Layout

The configuration control surfaces used in this simulation are as shown. Wing controls on this configuration consist of leading-edge flaps, trailing-edge flaps and flaperons. Control surface 1 is a pure flap and has a range of rotation from 0 to 40 degrees. Control surface 3 is called the inboard flaperon and is biased to the same position as control surface 1, it also can rotate ± 10 degrees from its biased flap position. Control surfaces 5 and 7 are also flaperons. They are biased to 5 degrees trailing edge down if the inboard flaps are deployed and can deflect ± 35 degrees from this position. For purposes of this present low-speed simulation control surfaces 9, 11 and 13 are preset to 30, 30 and 45 degrees respectively while horizontal and vertical tail deflections are limited to ± 20 degrees ± 25 degrees respectively.

CONTROL SURFACE LAYOUT



| Number | Area, m ² (ft ²) each | δ , deg |
|-------------------|---|------------------------|
| 1 | 11.734 (126.3) | 0 - 40 |
| 3 | 8.101 (87.2) | 0 - 40 |
| 5 | 4.692 (50.5) | 5 |
| 7 | 7.665 (82.5) | 5 |
| 9 | 15.440 (166.2) | 30 |
| 11 | 16.397 (176.5) | 30 |
| 13 | 8.454 (91.0) | 45 |
| Elevator ± 20 | | Vertical tail ± 25 |

Flight Control System

Three basic types of flight control systems are currently used in the simulation. These vary in complexity from a basic stick-to-surface command system to an attitude hold system and are described in the accompanying figure. Flight control system 1 is a basic non-augmented stick to surface system. Although this system would not be used on an actual aircraft it is useful to examine the non-augmented aircraft flying qualities. Flight control system 2 is a rate command system and incorporates some basic stability augmentation concepts, such as pitch rate and roll rate dampers. This system does provide a "flyable" study configuration but is not considered adequate. Flight control system 3 is representative of current technology and is more complex than either of the other two systems. It is a rate command and attitude hold type control system. This system incorporates various feedback loops and provides pitch and roll attitude hold, wing leveler, and aileron rudder interconnect. This is the default system used for the present research simulation.

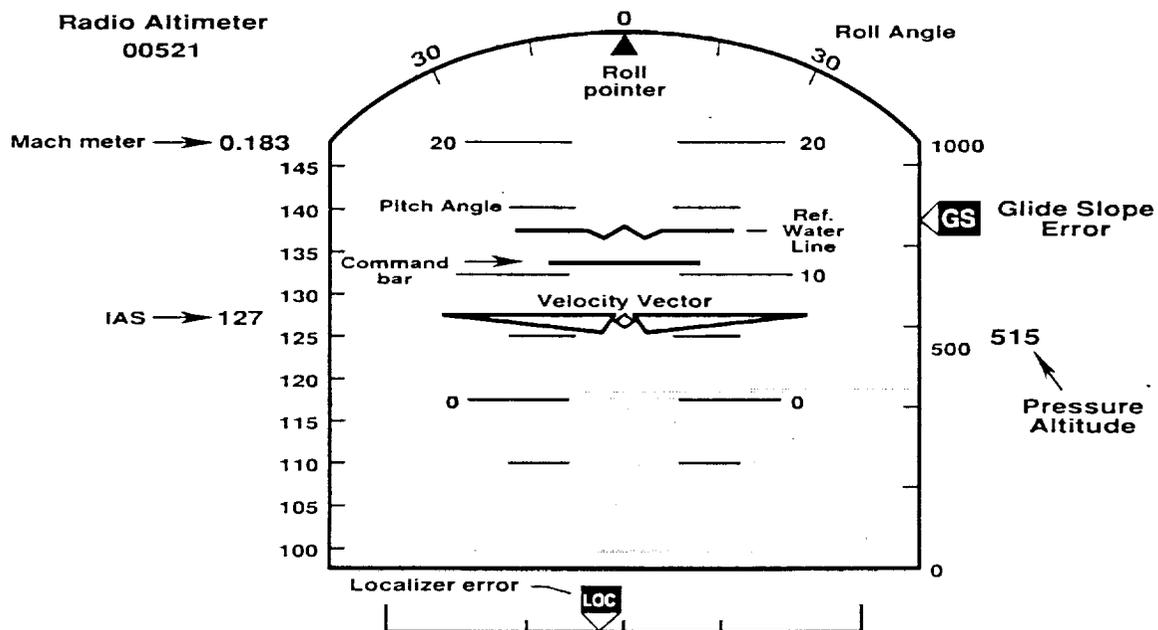
FLIGHT CONTROL SYSTEM

| Control System | Pilot Command Type | Descriptive Comments |
|----------------|--------------------------------|---|
| 1 | Acceleration command | <ul style="list-style-type: none">• Stick to surface servos |
| 2 | Rate command | <ul style="list-style-type: none">• Hi-gain pitch rate damper• Roll rate feedback |
| 3 | Rate command and attitude hold | <ul style="list-style-type: none">• Pitch and roll attitude hold• Wing leveler• Aileron-rudder interconnect |

Electronic Attitude Director Indicator (EADI)

The accompanying figure shows the Electronic-Attitude-Director Indicator (EADI). This instrument is located centrally in the instrument panel and has been found to provide the pilot with the majority of the necessary flight information. On the periphery of the EADI starting at the lower left hand corner moving upwards are indicated airspeed (IAS) in knots, Mach meter and radio altimeter. Roll bank angle is displayed across the top of the EADI. Proceeding down the right side on this instrument, pressure referenced altitude and glide slope error information are displayed; while on the bottom of the instrument, localizer information is displayed. Localizer error is referenced to the extended runway centerline, and glide slope error is referenced to a 3 degree glide slope. In the center of the instrument pitch angle bars are displayed along with the aircraft reference waterline. The triangular icon in the center on the EADI is the velocity vector which continuously displays where the aircraft is going. The pitch command bar is also displayed in the center of the EADI and, for this investigation is configured such that the aircraft will have a 4% climb gradient when the command bar is on top of the reference waterline bar.

ELECTRONIC ATTITUDE DIRECTOR INDICATOR (EADI)

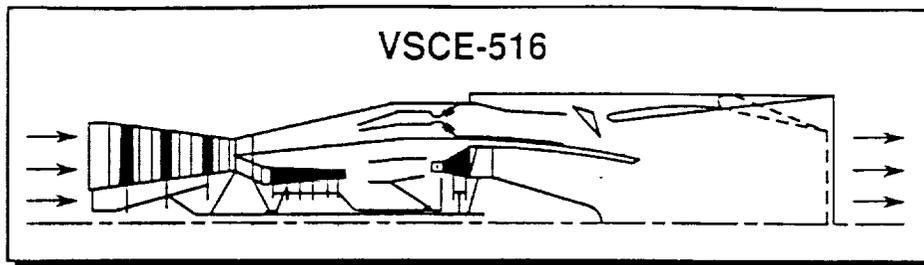


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VSCE-516 Characteristics

The AST-105 configuration is equipped with four Pratt-Whitney VSCE-516 engines. They are dual-stream duct-burning low-bypass ratio turbo-fan engines and make use of an inverted velocity profile for noise reduction. Engine characteristics used in the simulation are shown. These characteristics are input for both the piloted simulation and the Aircraft Noise Prediction Program (ANOPP). The piloted simulation requires net thrust data whereas ANOPP requires flow state variables.

ENGINE CHARACTERISTICS



Simulation Input:

- Performance variables
- * Net Thrust
 - $T \equiv F(T_{\max}, PSET)$
 - $T_{\max} \equiv F(H, M)$

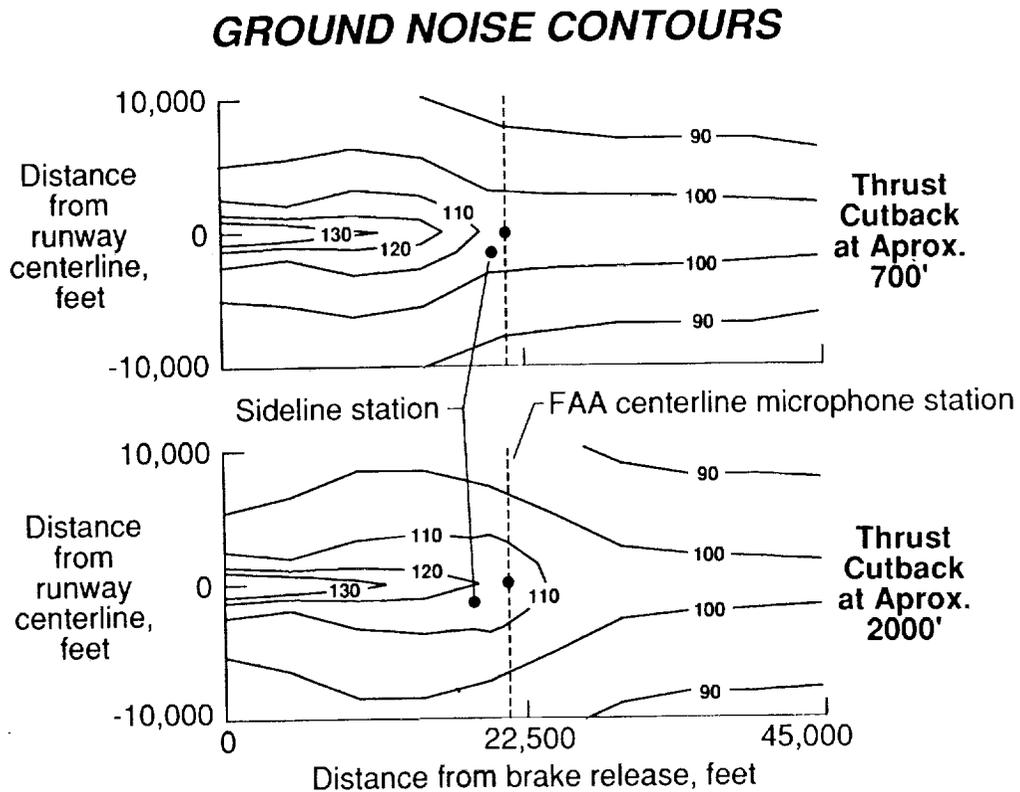
ANOPP Input:

- Flow state variables (primary & secondary streams)
- * Jet area $\equiv F(H, M, PSET)$
- * Mass flowrate $\equiv F(H, M, PSET)$
- * Total pressure $\equiv F(H, M, PSET)$
- * Total temperature $\equiv F(H, M, PSET)$

Note: Noise prediction is for jet mixing effect only

Ground Noise Contours

Very recently acquired results from the present piloted simulation are shown. These ground noise contours are presented to illustrate that the Visual Motion Simulation/Aircraft Noise Prediction Program (VMS/ANOPP) interface is operational.



HSCT Piloted Simulation Status

The status of the piloted simulation research is as indicated.

- **AST-105 aerodynamic data base and VSCE-516 engine deck incorporated in Visual Motion Simulation**
- **VMS/ANOPP interface developed**
- **AST baseline noise characteristics evaluated**
- **Advanced engine and advanced operating procedures investigations in progress**

HSCT Piloted Simulation Plans

Near term plans for the piloted simulation are as indicated. This study is intended to be a long term activity and will be updated to reflect current HSCT concepts as the experimental and computational data become available.

NEAR TERM PLANS

- Complete community noise evaluation of (AST-105) configuration, assess impact of advanced engines, advanced piloting procedures
- Enhance high-lift aerodynamics and evaluate community noise
 - C_L - Assume potential flow
 - C_D - Assume 90-percent suction
 - C_m - No pitchup, alternate trim concepts
- Evaluate community noise characteristics for NASA advanced baseline HSCT configuration

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